



What are requirements and why they are your friends...

A Benevolent Introduction to Requirements

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PI LaunchPad 2019*



Outline..

- Learning the lingo through a non-science example.
- What the formal structure of requirements are
- Why they are (or will become) your friends...



I'd like to build a house...

I require a house for people vs. house music, doll houses, cat houses, dog houses...

I require a house for two adults, three children, and two dogs.

Ooh! I can go on and on here! I need a master bedroom, three non-master bedrooms and 2.5 bathrooms. I'm iffy about a pool—if there is money...

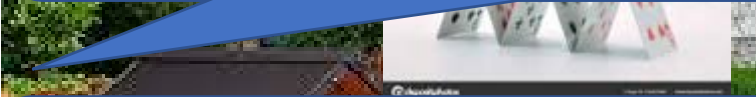
I ❤️ 🏠 🎵

Tell me your requirements...

Great!
Will be our objective!
Tell me more details!

Now we're talking!
Let's get into the details!

Let's formalize this..



What is a requirement?

They're not mysterious...

Requirement: The *agreed-upon* **need, desire, want, capability, capacity, function or demand** for **instruments, personnel, equipment, facilities, or other resources or services** by specified quantities for specific periods of time or at a specified time **expressed as a “shall” statement.**



General Language:

The [**noun**] shall [**quantitative verb**] [**aspect of the physical system**]
[**preposition**] [**verification parameter(s)**].



More in the interactive section!

The Language of Requirements...

Contains a
“shall” in it..

Conveys
expectations
for what is to
be delivered

A way to
clearly
communicate

Contains one
thought per
statement

Single
interpretation

Active
Voice:
*“Who” shall
“what”?*

Plain English

No
“and/ors”

Stated
Positively
*“shall” vs.
“shall not”*

Objective: The mission is to build a house.

Level 1: The mission shall build a house for two adults, three children, and two dogs.

Objective

Level 1

System-Level

Level 2 - Project

- Specific flow from L1

Subsystem-Level

Level 3 (L3)

L3 – Room Subsystem Requirements

- Master Bedroom Parameters
- Non-Master Bedroom Parameters
- Bathroom Parameters

Component-Level



L4- Room System Component Level

- Room Component Requirements

Level 2:

- The house shall have one master bedroom.
- The house shall have three non-master bedrooms.
- The house shall have 2.5 bathrooms.

Level 3:

- The master bathroom shall be located on the second floor.

Level 4:

- The master bathroom shall have one shower.
- The master bathroom shall have one sink.
- The master bathroom shall have one toilet.

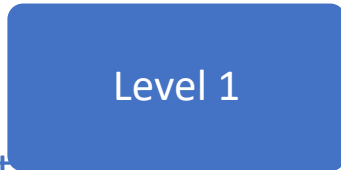
The [noun] shall [quantitative verb] [aspect of the physical system] [preposition] [verification parameter(s)].



Objective:
Your science
objective here



Level 1: The mission shall measure the elevation of at least 90% of the surface with 300 m postings and 10 m height precision

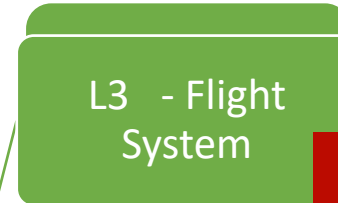


Jared will get into detail here!

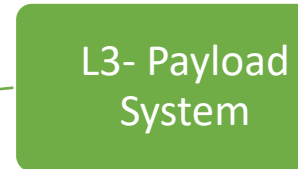
Level 2:
The project shall acquire single-pass interferometric synthetic aperture radar height measurements (≤ 10 m accuracy) over $\geq 95\%$ of Earth's surface.



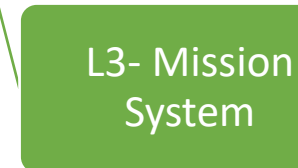
- Instrument-specific Flow from L1
- Science phase duration



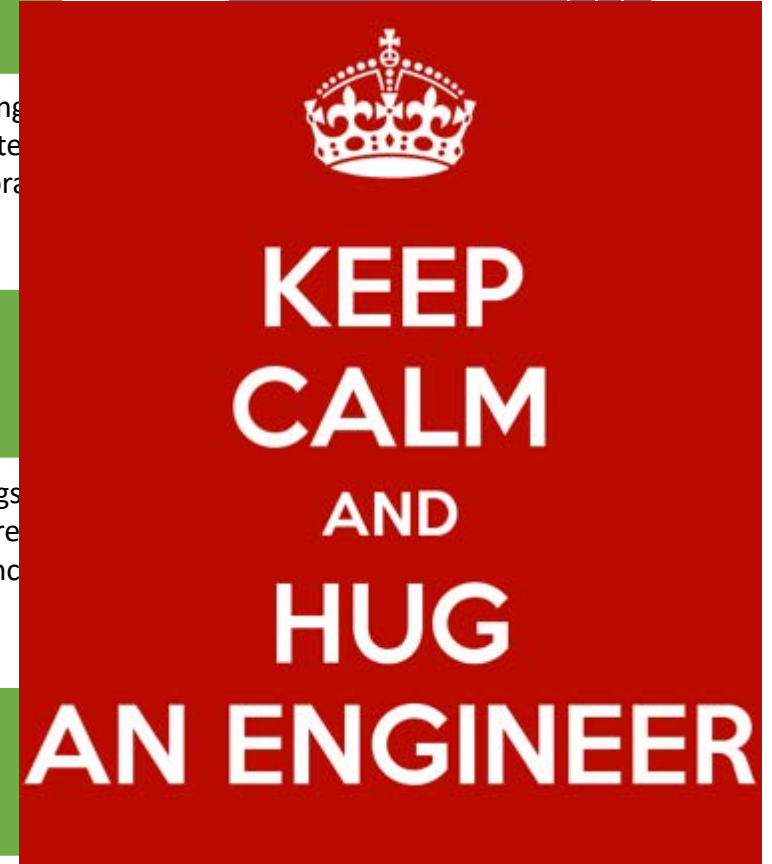
- Spacecraft pointing
- Downlink data rate
- Onboard data storage



- Instrument settings
- Instrument capture
- Instrument cadence



- Ground system architecture
- Data archive size
- Uplink/downlink frequency



Level 2s guide instrument function and performance details

Critical Requirement

A requirement where the consequence of not meeting the requirement *has significant impact or high sensitivity on the mission's ability to meet negotiated success criteria*, as assessed by the requirement owner.

If the number of bedrooms is not built, this will impact the ability to meet the level 1 requirement

Level 1: The mission shall build a house for two adults, three children, and two dogs.

Driving Requirement

A requirement where *compliance is deemed particularly difficult or the likelihood of needing additional resources to meet the requirement is significant*, as assessed by the requirement implementer.

Meeting a requirement, like having the majority of the bedrooms and bathrooms on the second floor in an environment with earthquakes may introduce additional challenges.

I would like to build a house.

Based on the budget and schedule, what can you live without and still achieve your mission?

DESCOPES: Baseline vs. Threshold?

- Number of Bedrooms
- Number of Bathrooms
- Number of Floors
- Backyard?
- Basement?
- Patio?
- Pool?
- Garage?
- Energy Source: Electrical/Solar/Geothermal?
- Other?

Baseline science requirements are the mission performance **requirements necessary to achieve the full science objectives of the mission.**

I want it all, I want it all, I want it all...



Threshold science requirements are those mission performance **requirements necessary to achieve the minimum science acceptable for the investment.**

You can't always get what you want, but if you try sometimes, you just might find, you get what you need...

Why should they become my friends?

- **The power to define your own path and prove it.** You're not surprised by what you get ("deliverables") or what your deliverables will do (and your stakeholders aren't either).
- **Mission Flexibility** When your requirements are written with baselines/thresholds and in a flowed down manner, you'll have the ability to adapt when situations change (and they will!)
- **Verification and Validation** Did you do (in a unique and quantitative way) what you said you were setting out to do?
- **Clear communication to your team, your stakeholders and the community.**



They won't stifle your creative mojo...

Potential Resources

Movies:

Mr. Blandings Builds His Dream House

The Money Pit

Texts:

The NASA Systems Engineering Handbook

Exploring Requirements Before, Gause and Weinberg

Visualizing Project Management by Forsberg, Mooz and Cotterman

Practical Project Management for Engineers by N. Patel=



Types of Requirements



Functional Requirements

Defines the function that needs to be performed



Performance Requirements

Defines how well the functions need to be performed



Interface Requirements

Define how design elements relate to one another or to other systems



Environment Requirements

Define internal and external environments for flight segment elements



Reliability Requirements

Define probability of failure under specified operating conditions



Safety Requirements

Define human, environmental and asset safety needs

What the initial focus is for most science teams...



Functional Requirements



Performance Requirements



Interface Requirements



Environment Requirements

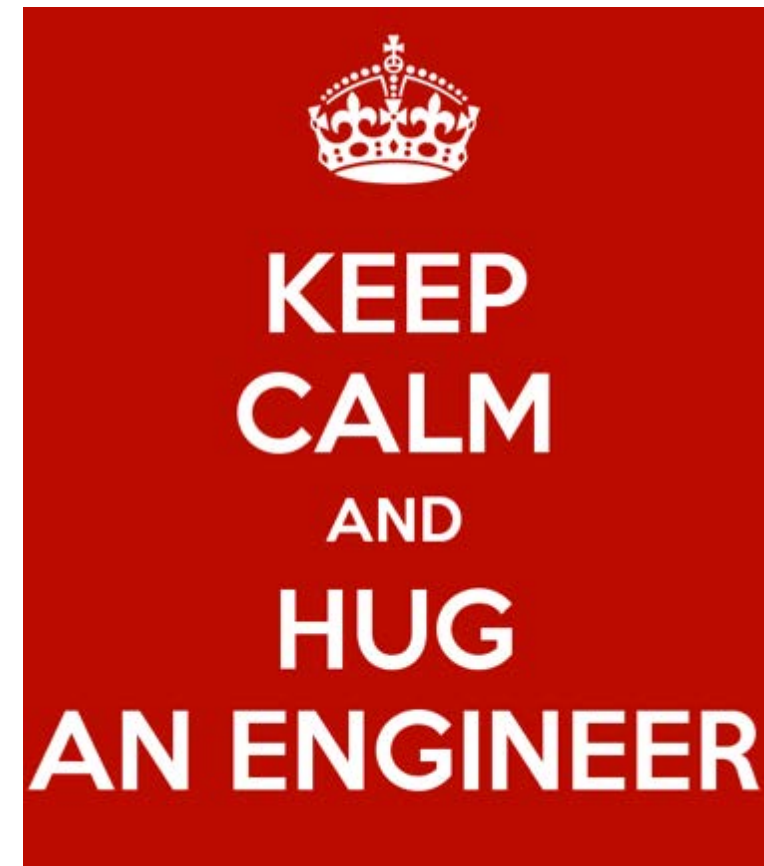


Reliability Requirements



Safety Requirements

...your engineering colleagues usually get to work the rest, so...



BACKUP

Requirements tidbits for after your project gets going.



Requirements are not
always static during
development



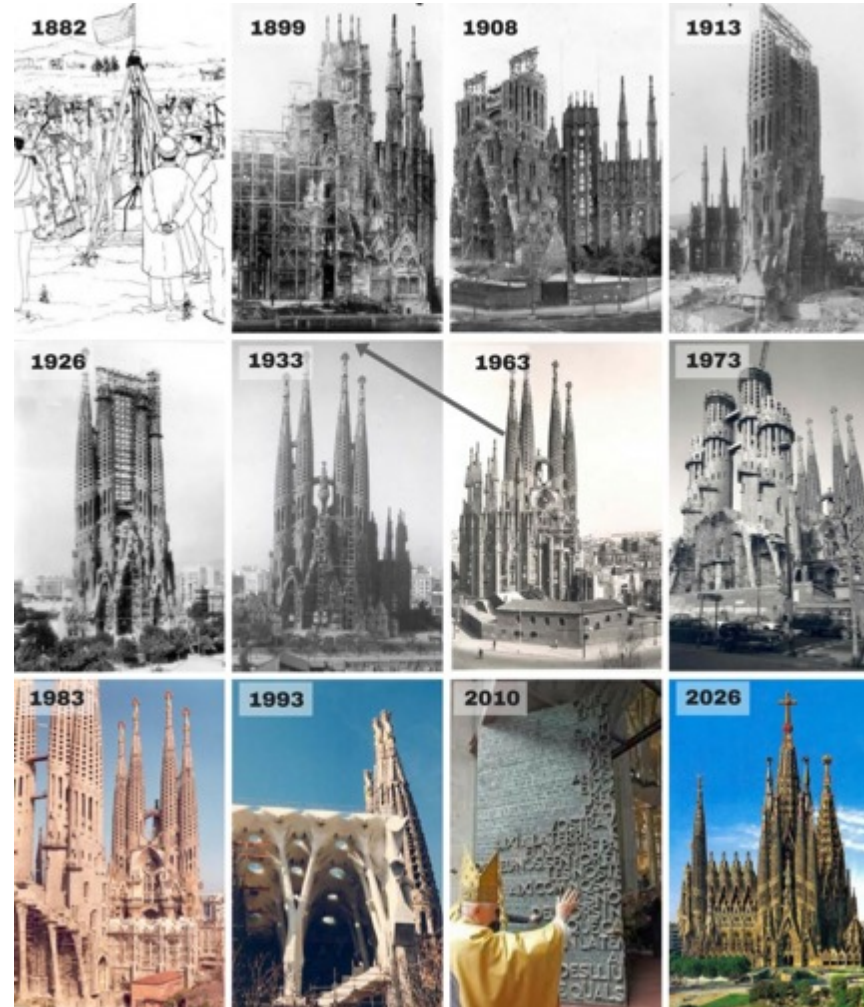
Requirements may need
to be added.



Requirements are
eventually “frozen”
*...they won't change much, if at all, after
that...*

Requirements can “creep”

Think Antonio Gaudi's Sagrada Familia...



- Adding in capabilities almost always costs resources: money, schedule, labor
- Do you really need that capability or is it a “desirement” (a desired capability)?

How to write ambiguous requirements..

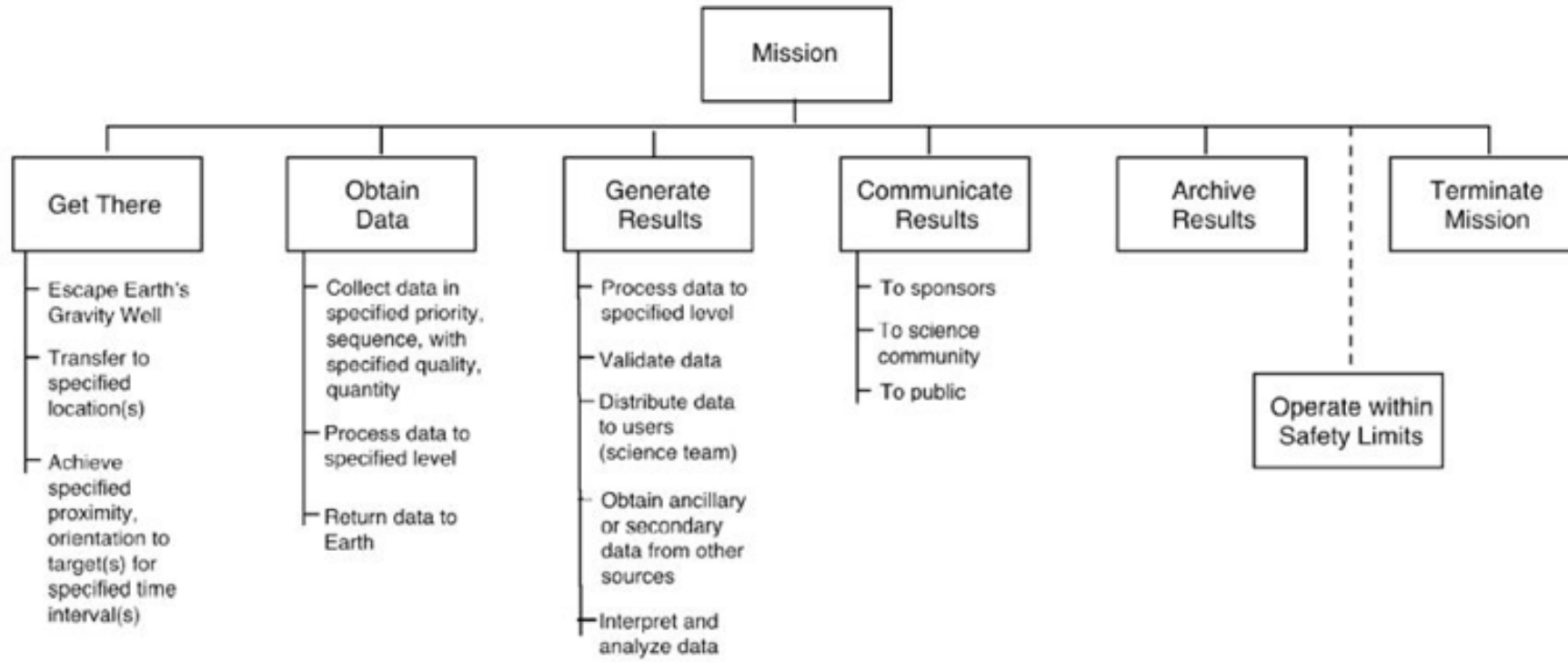
- And/or in the requirements statement
- Multiple requirements in one sentence.
- Use of vague adjectives/adverbs



Vague phrases, adjectives and adverbs

- | | | | | |
|---------------|--------------|---------------|---------------|----------------------|
| • About | • Affordable | • Stable | • Necessary | • Safe |
| • Acceptable | • Average | • Sufficient | • Possible | • Flexible |
| • Appropriate | • Optimum | • Significant | • Known | • But not limited to |
| • Applicable | • Normal | • Various | • Approximate | • Be able to |
| • Average | • Effective | • Variable | • TBD | • As appropriate |
| • Adequate | • Immediate | • Typical | • TBR | • Be capable of |
| • Adjustable | • Major | | • Easy | |

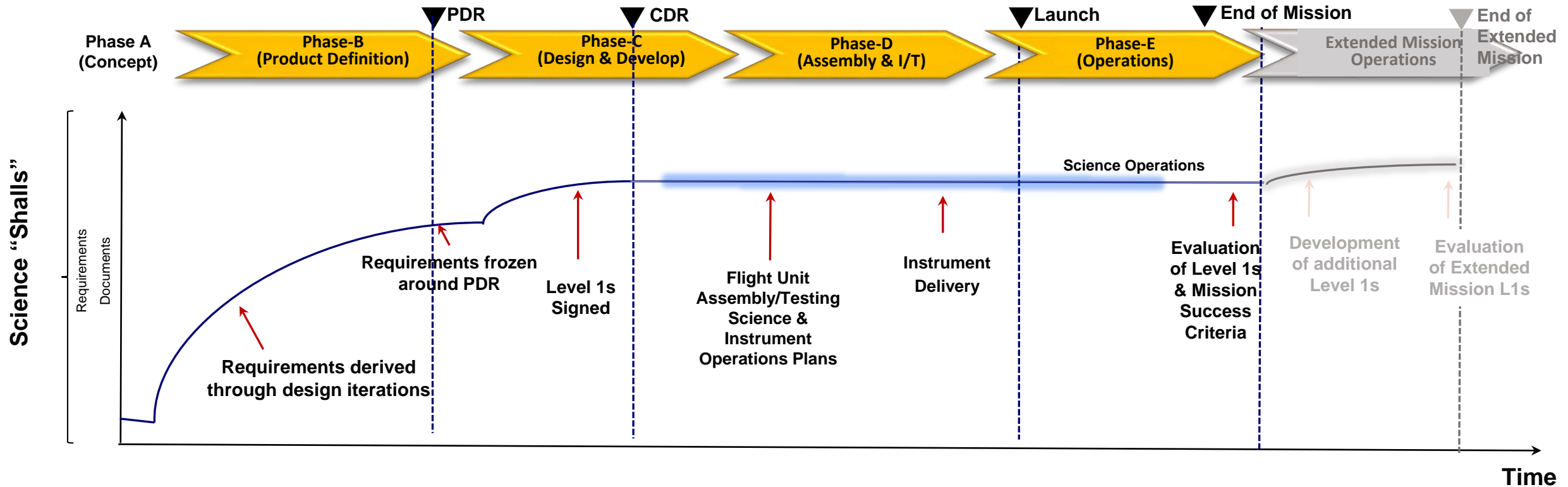
Logical Decomposition of Science in a Standard Mission



Applicable to:

- Flybys
- Orbiters (Earth and Planetary)
- In situ missions
- Constellations
- Heliocentric observers
- Sample return missions
- Occultation experiments

The Science “Shalls” Through the Life Cycle





**What the scientists
wanted**



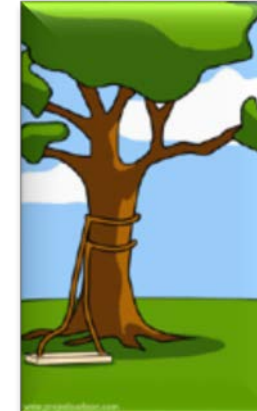
**What the PM
envisioned**



**How the engineer
saw it**



**How the
requirements were
documented**



After PDR...



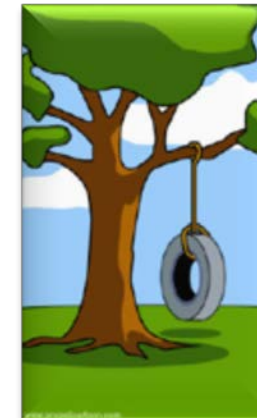
After CDR...



**What the project
was going to cost**



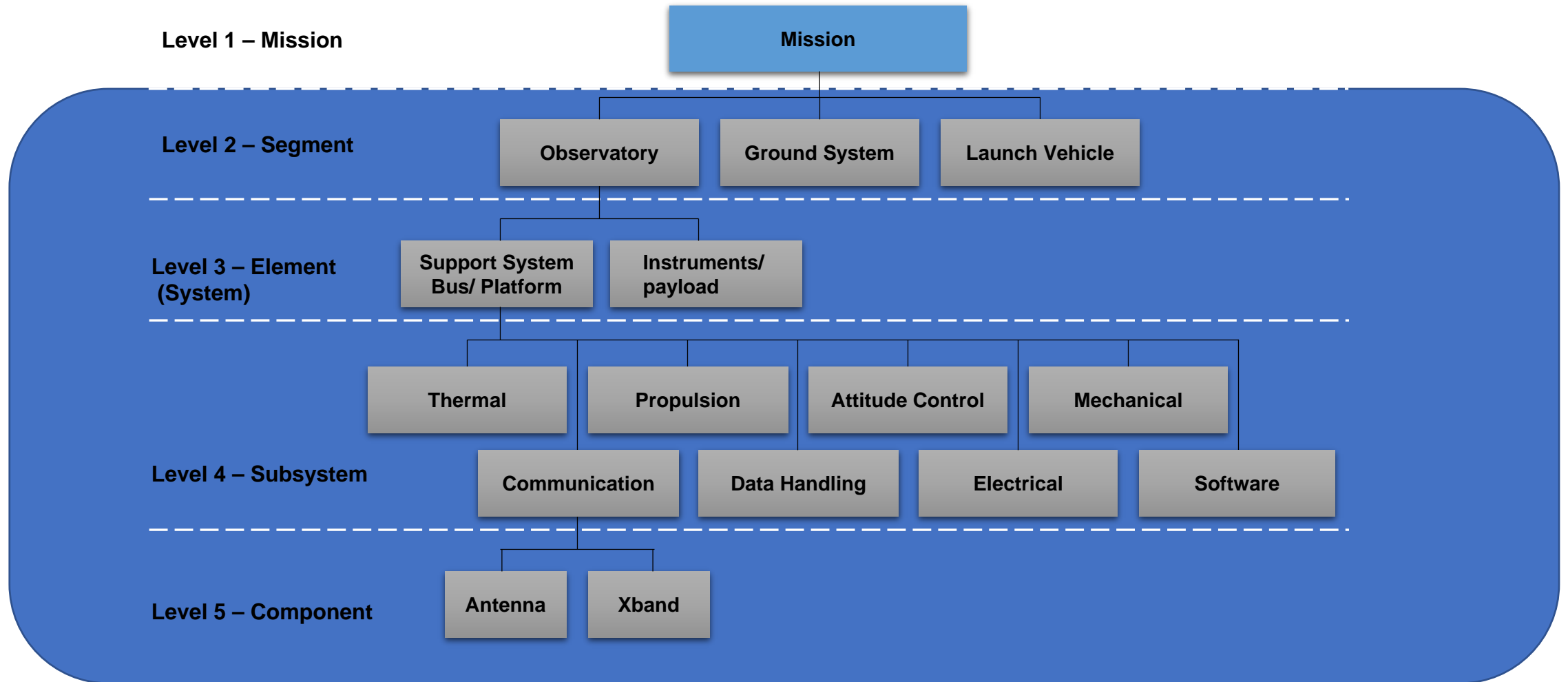
**What the project
could afford**

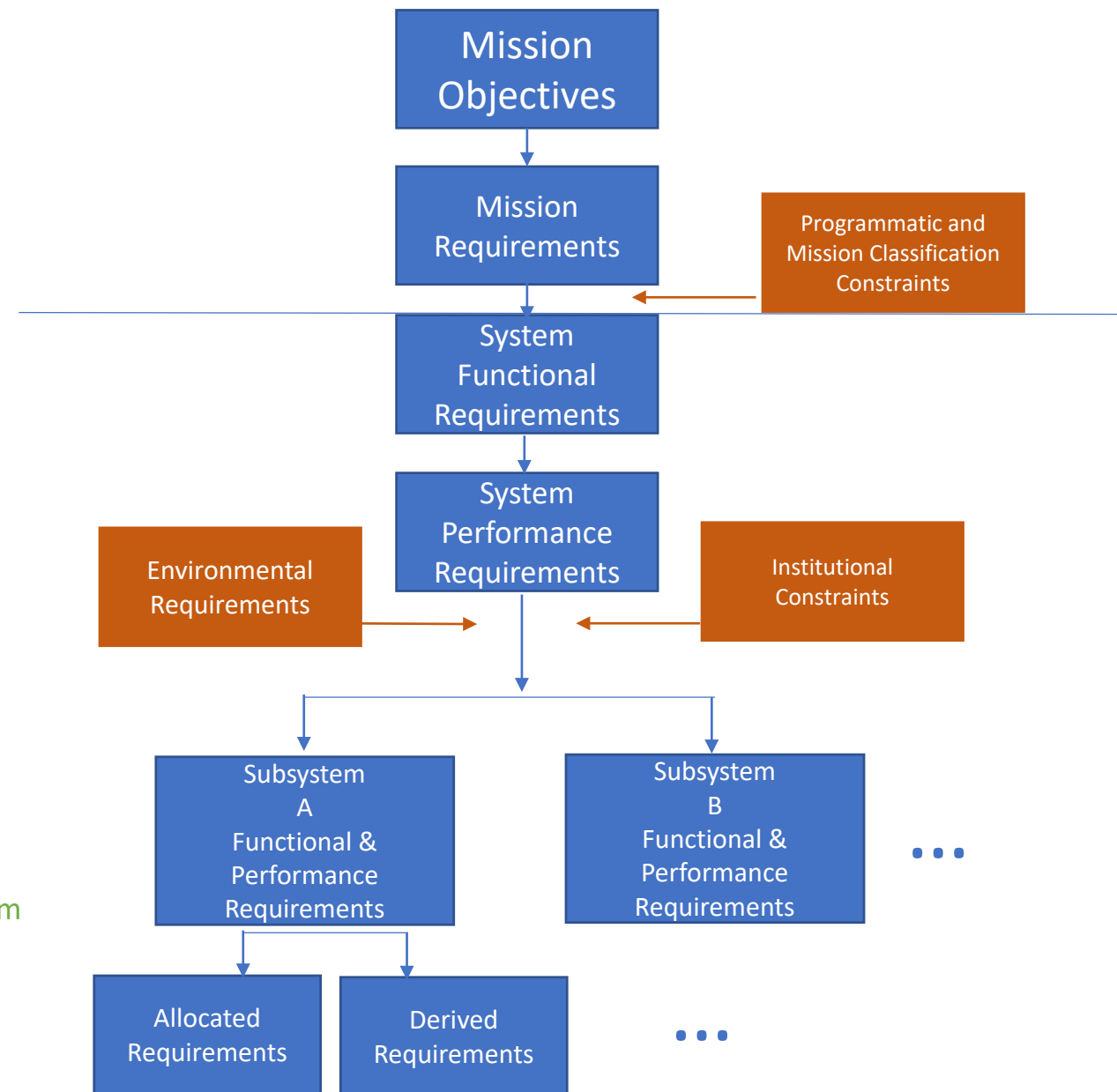
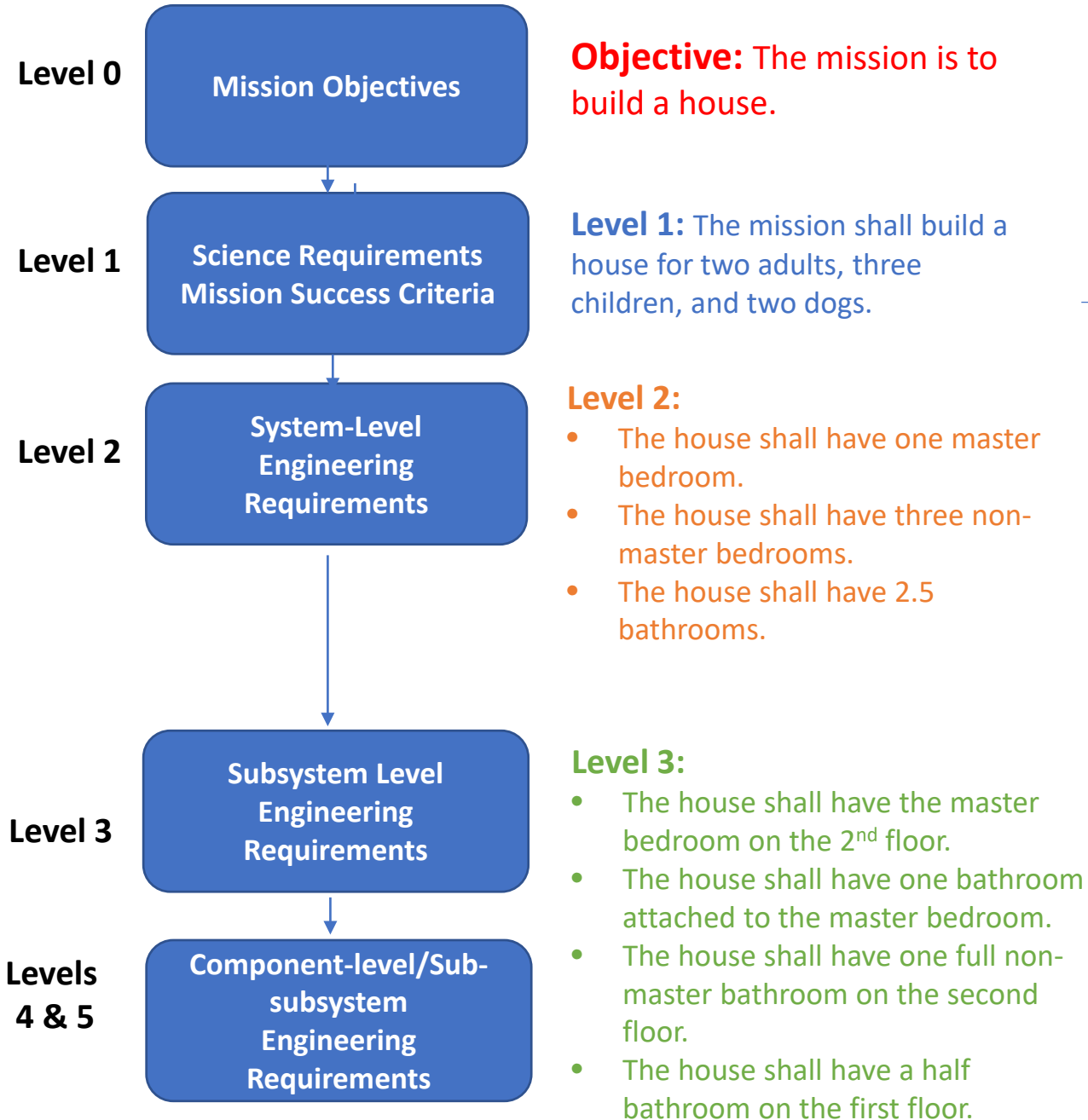


**What the scientists
really needed**

Notional System Hierarchy for Requirements

Lisa will talk about this more!





Requirement Decomposition

- The process by which requirements defined at one level are allocated or derived into implementable elements.
- It is **NOT** writing the same requirement at the next lower level as a child of a higher level requirement.
- It is **NOT** writing parents for lower level requirements.

Allocating = Distributing a resource or functional requirement

Deriving = Distributing a requirement by analysis or modeling

Characteristics of Sound Requirements...

- **Unambiguous**-only one interpretation
- **Understandable** –the interpretation of each requirement is clear
- **Correct**-a requirement the system is in fact required to do
- **Concise**-no unnecessary information is included in the requirement
- **Traced**-each requirement is traced to some statement/document
- **Traceable**- each derived requirement must be traceable to an originating requirement
- **Design independent**- does not specify a particular solution or portion of the solution
- **Verifiable** – a finite process can be conducted to check that the requirement has been attained
- **Unique** – requirements are not overlapping or redundant with other requirements
- **Consistent**-(a) internally consistent—no two subsets of requirements conflict and (b) externally-no subset of requirements conflicts with external documents from which the requirement is traced.
- **Comparable**-relative priority of a particular requirement can be compared to other requirements
- **Modifiable**-changes to the requirements can be made easily, consistently, and completely
- **Attainable**-solutions exist within cost/schedule/performance constraints

The “Mary Had a Little Lamb” test...

What is the significance of each word in your requirements?

An Example:

“Mary had a little lamb, whose fleece was white as snow.
Everywhere that Mary went the lamb was sure to go. “

Mary **had** a little lamb.

Used to own? Still owns?

Mary had a **little** lamb.

Little in size? Little in age? Little in weight? How little?

Mary had a little **lamb**.

A young sheep? A young child? A lamb-orghini?

Is the requirement free of ambiguities? Unverifiable terms?

Concept of Operations (ConOps/OpsCon)

A description of how the system will be operated during the missions phases in order to meet stakeholder expectations. Timelines and graphics are typical description methods.

Typical ConOps Timeline Elements:

- Launch
- Cruise (and instrument checkout)
- Orbit Insertion/Landing/Flyby
- Instrument Commissioning
- Prime Science Mission
- Extended Science Mission
- Decommissioning/Deorbit/End of Mission activities

Includes command and data transmission sequencing, science operations controls, logistics (resupply

In developing the ConOps, you may make some discoveries....

Requirements
Revealed!

Changes
In ops Sequences!

Requirements
Removed!

New Use
Cases!



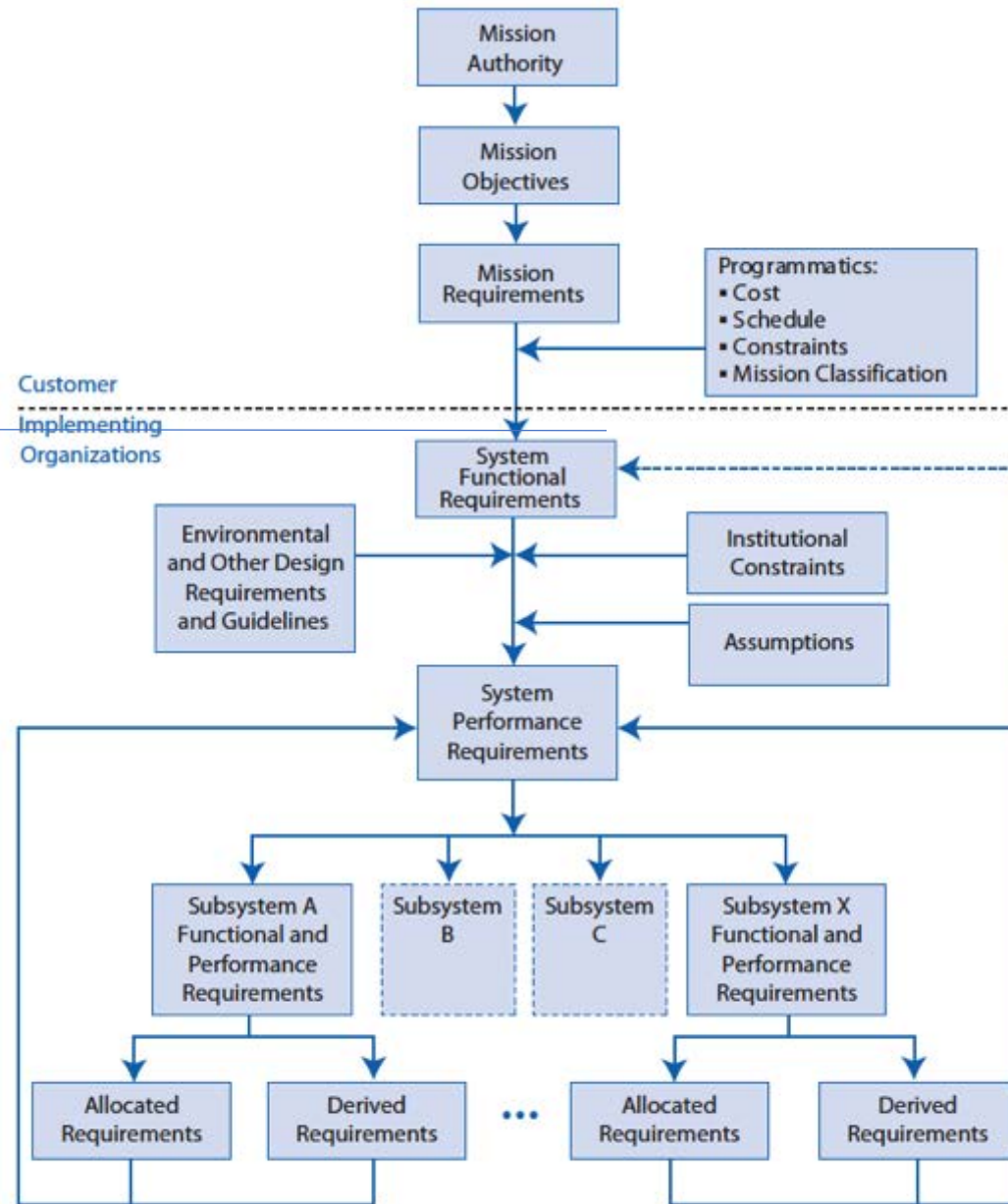


Figure 4.2-3 The flowdown of requirements